Evaluation of Drawdown and Sources of Water in the Mississippi River Alluvium Caused by Hypothetical Pumping, Muscatine, Iowa

By Keith J. Lucey

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
million gallons per day (Mgal/d)	3,785	cubic meters per day
gallon per minute (gal/min)	0.06309	liter per second
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per day (ft^3/d)	0.02832	cubic meter per day

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Altitude, as used in this report, refers to distance above or below sea level.

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Abstract

A study was conducted to evaluate drawdown and volumetric changes in sources of water in the Mississippi River alluvium caused by hypothetical pumping. A steady-state, ground-water flow model was constructed for a previous study to simulate February 1993 hydrologic conditions, which were assumed to be an acceptable estimate of the ground-water system at equilibrium. The flow model was modified for this study to simulate six hypothetical pumping scenarios: five pumping scenarios to simulate hypothetical pumping at five pumping scenario sites, and a total pumping scenario to simulate cumulative hypothetical pumping from the five pumping scenario sites.

The evaluation of drawdown for the six hypothetical pumping scenarios indicates that hypothetical pumping causes simulated drawdown that varies from about 10 ft to greater than 50 ft relative to February 1993 conditions at the five hypothetical pumping scenario sites. The simulated drawdown is less than half of the estimated saturated thickness of the alluvium during February 1993 at these sites.

The primary sources of water (inflows) to the alluvium needed to balance the increased ground-water withdrawals (outflows) caused by hypothetical pumping are a combination of increased river leakage and decreased leakage to Muscatine Slough. Compared to February 1993 conditions, larger inflow rates occur as river leakage from the Mississippi River for the six hypothetical pumping scenarios. However, smaller outflow rates to Muscatine Slough compared to February 1993 conditions indicate that an important source of water for hypothetical pumping is ground-water discharge that would have become streamflow in the slough.

Increased pumping at the hypothetical pumping scenario sites could affect long-term water quality and hydrology in the study area. The greater amounts of river leakage might affect overall ground-water quality in the alluvium. The lesser amounts of ground water being discharged to streamflow could have a long-term impact on the hydrology of the slough and adjacent wetland areas.

The simplified steady-state flow model does not account for dynamic (transient) conditions (natural or development-related). The steady-state model does not indicate time needed to reach new equilibrium conditions. Attaining equilibrium might take many years and is complicated by varying climatic and hydrologic conditions; noncontinuous pumping and pumping that is cycled among well fields; and changing and seasonally varying irrigation pumpage.

INTRODUCTION

Sand and gravel deposits of the Mississippi River alluvium in Muscatine and Louisa Counties, Iowa, provide a dependable source of large quantities of ground water for municipal, industrial, and agricultural uses. Municipal and industrial development of the ground-water resource is expected to continue, and water managers need a method to evaluate the effects of additional ground-water withdrawals on the ground-water resource to locate additional pumping centers in areas that would minimize any negative effects, such as from well interference or degradation in water quality.

A cooperative study of the Mississippi River alluvium near Muscatine, Iowa, was conducted by Muscatine Power and Water (MPW) and the U.S. Geological Survey (USGS) from January 1992 through September 1995. Hydrogeology and water quality were investigated in an 80-mi^2 study area in Muscatine and Louisa Counties in Iowa and Rock Island and Mercer Counties in Illinois (fig. 1), and the results were documented in a report by Lucey and others (1995). Alluvium overlies carbonate, sandstone, and shale bedrock in the Mississippi River valley, and the thickness of the alluvium varies from 40 ft in the northeast to more than 140 ft in the southern and western parts of the study area. The alluvium is between 60 and 100 ft thick at the Grain Processing Corporation and MPW Main well fields and generally is about 140 ft thick at the MPW Grandview, Progress Park, Iowa-Illinois Gas and Electric Company, and Monsanto well fields (fig. 2). More detailed descriptions of aquifer characteristics, geology, and hydrology of the study area are included in Hansen and Steinhilber (1977) and Lucey and others (1995).

A ground-water flow model was constructed by Lucey and others (1995) using the USGS computer program MODFLOW (McDonald and Harbaugh, 1988) to simulate February 1993 hydrologic conditions, which were assumed to be an acceptable estimate of the ground-water system at equilibrium (steady-state condition). Streamflow and stage measurements in Muscatine Slough for February 1993 indicate a period of generally stable conditions; annual ground-water withdrawals from the well fields increased less than 2 percent from 1990 through 1992; and ground-water levels measured in February 1993 were approximately equal to mean annual ground-water levels for 1990 through 1992 determined from mean monthly measurements (Lucey and others, 1995). The ground-water flow model consists of three layers to represent the alluvium and part of the bedrock. A 30-row by 24-column grid was used to discretize each successive model layer into a series of 2,000-ft by 2,000-ft cells (fig. 2). Total ground-water withdrawals (pumping) from the alluvium were simulated at 6,091,000 ft^3/d (about 45.5 million gallons per day (Mgal/d)) at pumping cells that represent well fields operating during February 1993 (fig. 2). Model results were used to aid in improved understanding of the complex flow system and to quantify sources of water in the alluvium.

In 1996, MPW and the USGS initiated a second study to evaluate drawdown and sources of water in the alluvium caused by hypothetical pumping. The objectives of the study were to evaluate the effects of six hypothetical pumping scenarios on:

(1) water levels (drawdown) in the Mississippi River alluvium; and

(2) quantitative changes in sources of water in the Mississippi River alluvium.

The purpose of this report is to present results of model simulations for the six hypothetical pumping scenarios. The steady-state ground-water flow model constructed by Lucey and others (1995) was modified for five pumping scenarios to simulate hypothetical pumping at five hypothetical pumping scenario sites, and for one total pumping scenario that simulates the cumulative effect of hypothetical pumping from all five pumping scenario sites. Simulated effects on drawdown and quantitative changes in sources of water in the Mississippi River alluvium caused by hypothetical pumping are presented. The flow model can be used to estimate general effects of additional pumpage for selected hypothetical pumping scenarios compared to the February 1993 assumed equilibrium condition. The number of wells and the amounts of hypothetical pumping at each of the five pumping scenario sites were selected in consultation with MPW (J. Doering, Muscatine Power and Water, oral commun., December 1996).

Information in this report can be used by water managers to evaluate the estimated effects of additional ground-water withdrawals on the ground-water resource as an aid in locating future wells and pumping centers. Because alluvial aquifers commonly provide sources of water for municipal, industrial, and agricultural use, it is important to improve understanding of ground-water flow and the interaction between surface water and ground water in alluvial systems.

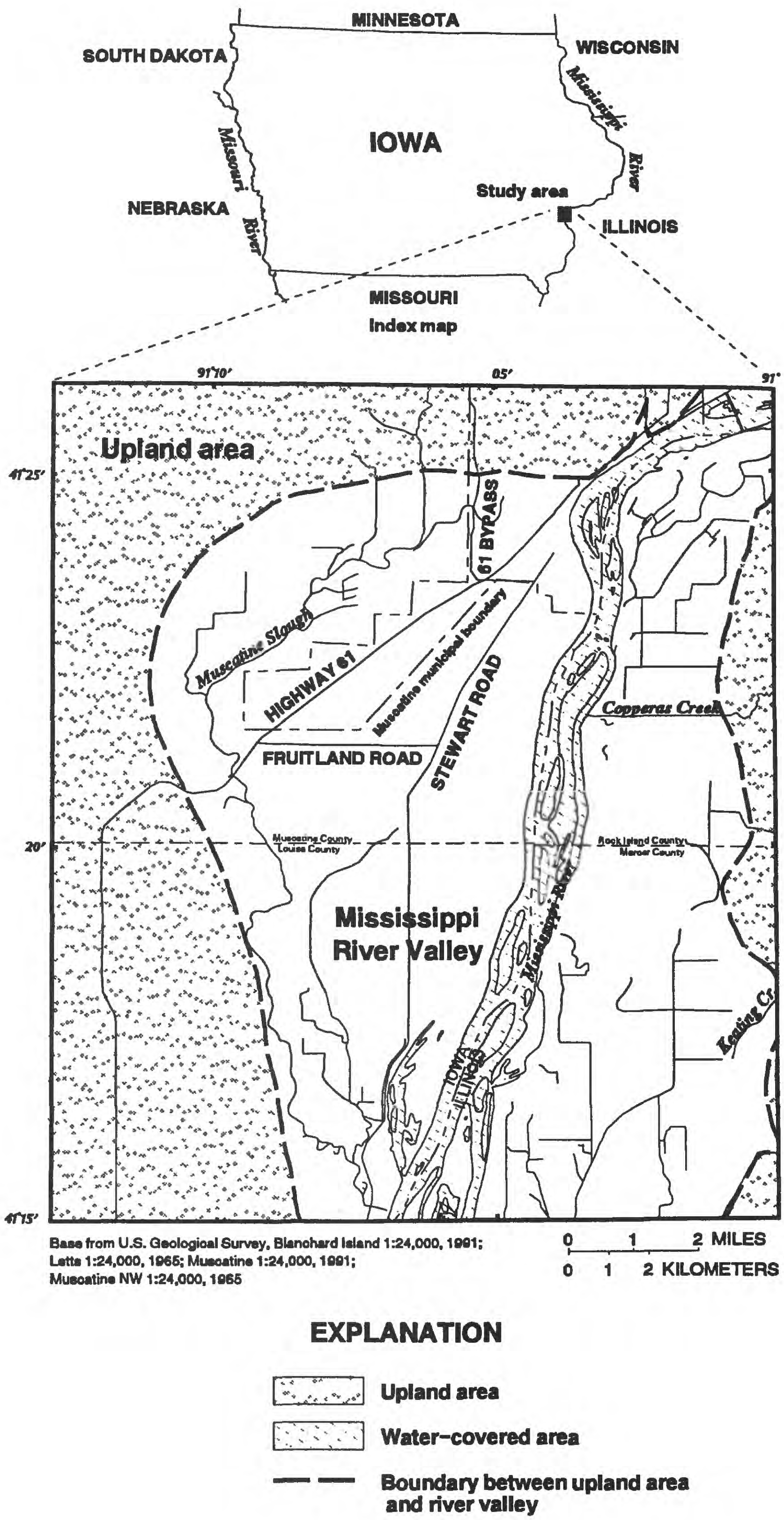


Figure 1. Location of study area.

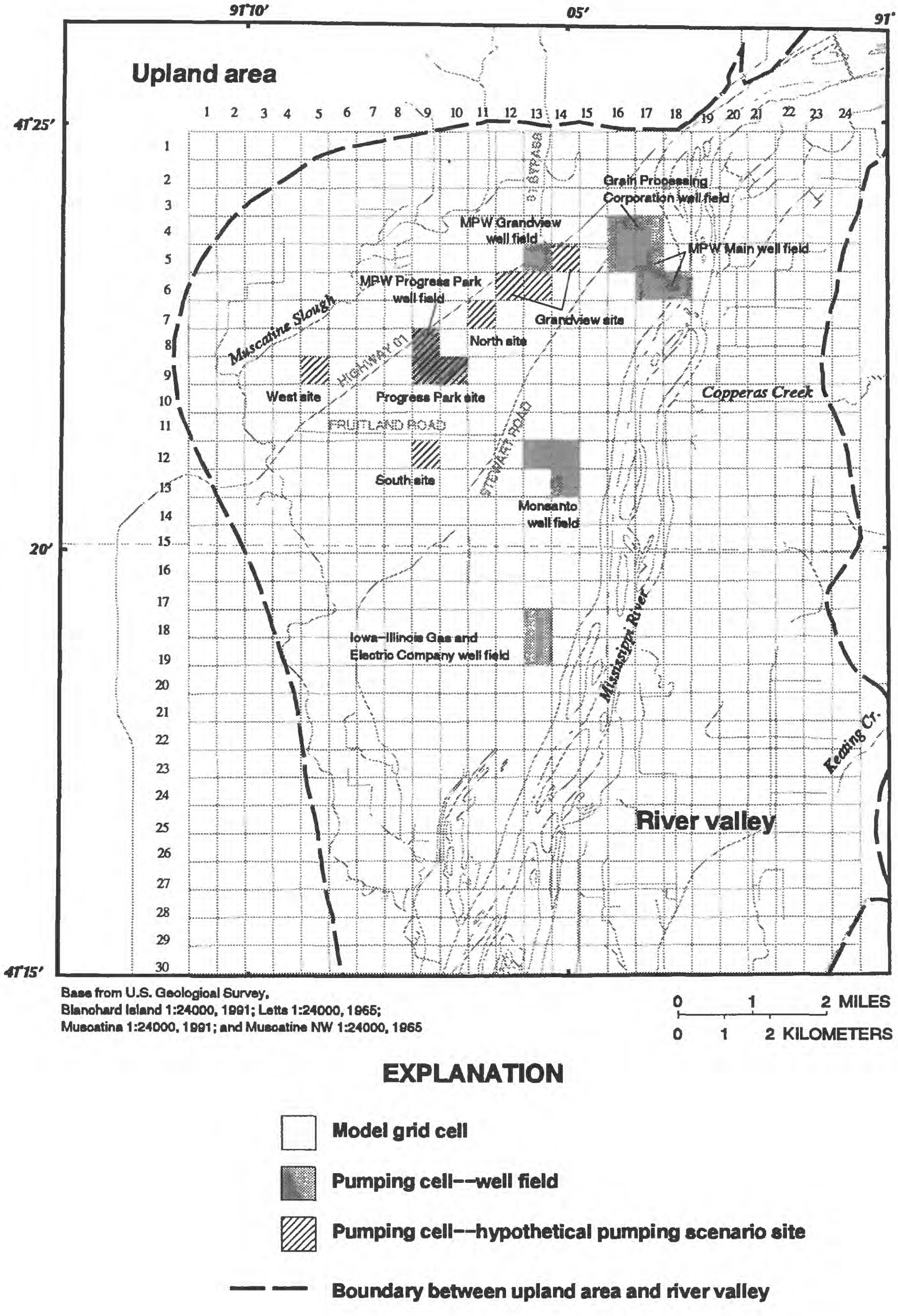


Figure 2. Model grid and pumping cells.

DESCRIPTION OF PUMPING SCENARIOS

Steady-state simulations of six hypothetical pumping scenarios were prepared. For each pumping scenario, pumping at one or more pumping scenario sites was added to the previously-modeled pumping of 6,091,000 ft^3/d (about 45.5 Mgal/d) at well fields operating during February 1993 (Lucey and others, 1995). The six pumping scenarios were prepared by adding pumping to the flow model at five pumping scenario sites (fig. 2) as follows:

(1) Grandview pumping scenario (GV) - hypothetical pumping of 2,021,000 ft^3/d (about 15.12 Mgal/d) at the Grandview pumping scenario site, located adjacent to the MPW Grandview well field, to account for seven municipal wells that produce 1500 gallons per minute (gpm) each. Since construction of the flow model by Lucey and others (1995), three wells have been added to the MPW Grandview well field. Pumping from those three wells is included in hypothetical pumping from the seven wells at the Grandview pumping scenario site.

(2) Progress Park pumping scenario (PP) - hypothetical pumping of 2,021,000 ft^3/d (about 15.12 Mgal/d) at the Grandview pumping scenario site and hypothetical pumping of 1,155,000 ft^3/d (about 8.64 Mgal/d) from four wells that produce 1500 gpm each at the Progress Park pumping scenario site. Hypothetical pumping from the four wells at the Progress Park pumping scenario site is simulated from the same model cells as pumping from the operating MPW Progress Park well field (fig. 2). The Progress Park pumping scenario site and MPW Progress Park well field are referred to separately in this report, so that results from hypothetical pumping near the operating MPW Progress Park well field can be described.

(3) North pumping scenario (N) - hypothetical pumping of 2,021,000 ft^3/d (about 15.12 Mgal/d) at the Grandview pumping scenario site and hypothetical pumping of 1,155,000 ft^3/d (about 8.64 Mgal/d) from four wells that produce 1500 gpm each at the North pumping scenario site. The North pumping scenario site is located about midway between the MPW Grandview and Progress Park well fields.

(4) West pumping scenario (W) - hypothetical pumping of 2,021,000 ft^3/d (about 15.12 Mgal/d) at the Grandview pumping scenario site and hypothetical pumping of 1,155,000 ft^3/d (about 8.64 Mgal/d) from four wells that produce 1500 gpm each at the West pumping scenario site. The West pumping scenario site is located about 6000 ft west of the Progress Park pumping scenario site and MPW Progress Park well field.

(5) South pumping scenario (S) - hypothetical pumping of 2,021,000 ft^3/d (about 15.12 Mgal/d) at the Grandview pumping scenario site and hypothetical pumping of 1,155,000 ft^3/d (about 8.64 Mgal/d) from four wells that produce 1500 gpm each at the South pumping scenario site. The South pumping scenario site is located about 4000 ft south of the Progress Park pumping scenario site and MPW Progress Park well field.

(6) Total pumping scenario (TOT) - cumulative hypothetical pumping of 6,641,000 ft^3/d (about 49.68 Mgal/d) from 23 wells at the five pumping scenario sites.

Simulated hypothetical pumping from the 23 wells at the five pumping scenario sites reflects MPW's general 20-year plan for development of the groundwater resource. The pumping scenario sites were selected, in consultation with MPW, based on proximity to operating municipal well fields (MPW Grandview, MPW Progress Park, and MPW Main well fields shown in figure 2) to minimize development costs associated with extending pipelines to new wells or well fields. The thickness of the alluvium is more than 140 ft at each of the five pumping scenario sites, and the saturated thickness was about 120 ft to 130 ft in February 1993 (Lucey and others, 1995).

EVALUATION OF DRAWDOWN

Simulated drawdown relative to February 1993 conditions caused by hypothetical pumping for the six pumping scenarios are shown in figures 3-8. Drawdown of 1 ft or greater is shown for the six pumping scenarios in this study, because the comparison between simulated and measured water levels during construction of the flow model indicated a model error of about 1 ft (Lucey and others, 1995). The drawdowns shown represent those after new equilibrium conditions have been attained, although the times required to reach those conditions cannot be indicated by steady-state simulations.

For the Grandview pumping scenario, hypothetical pumping from seven additional municipal wells at the Grandview pumping scenario site results in simu-

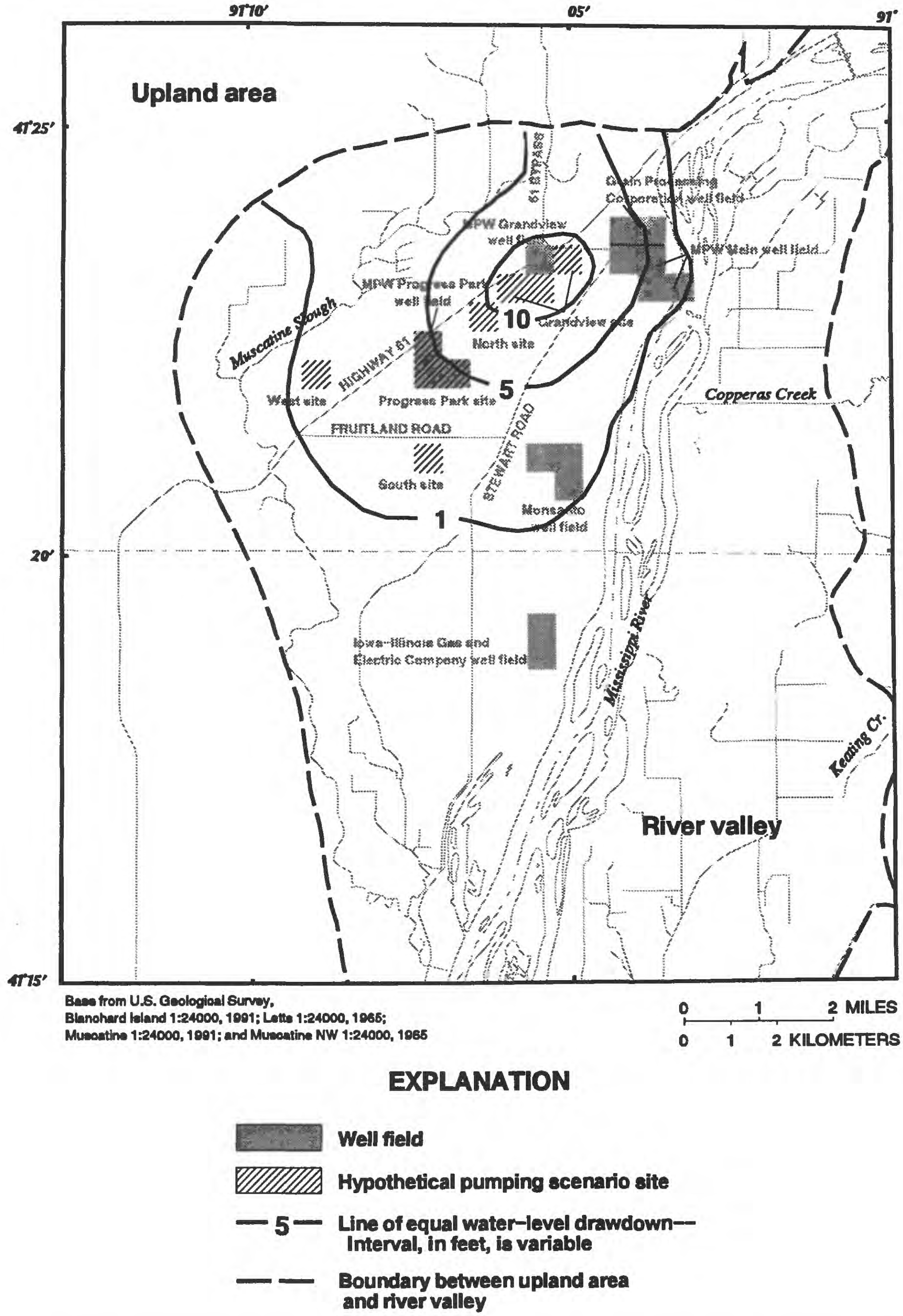


Figure 3. Simulated drawdown caused by hypothetical pumping at the Grandview pumping scenario site (Grandview pumping scenario, GV).

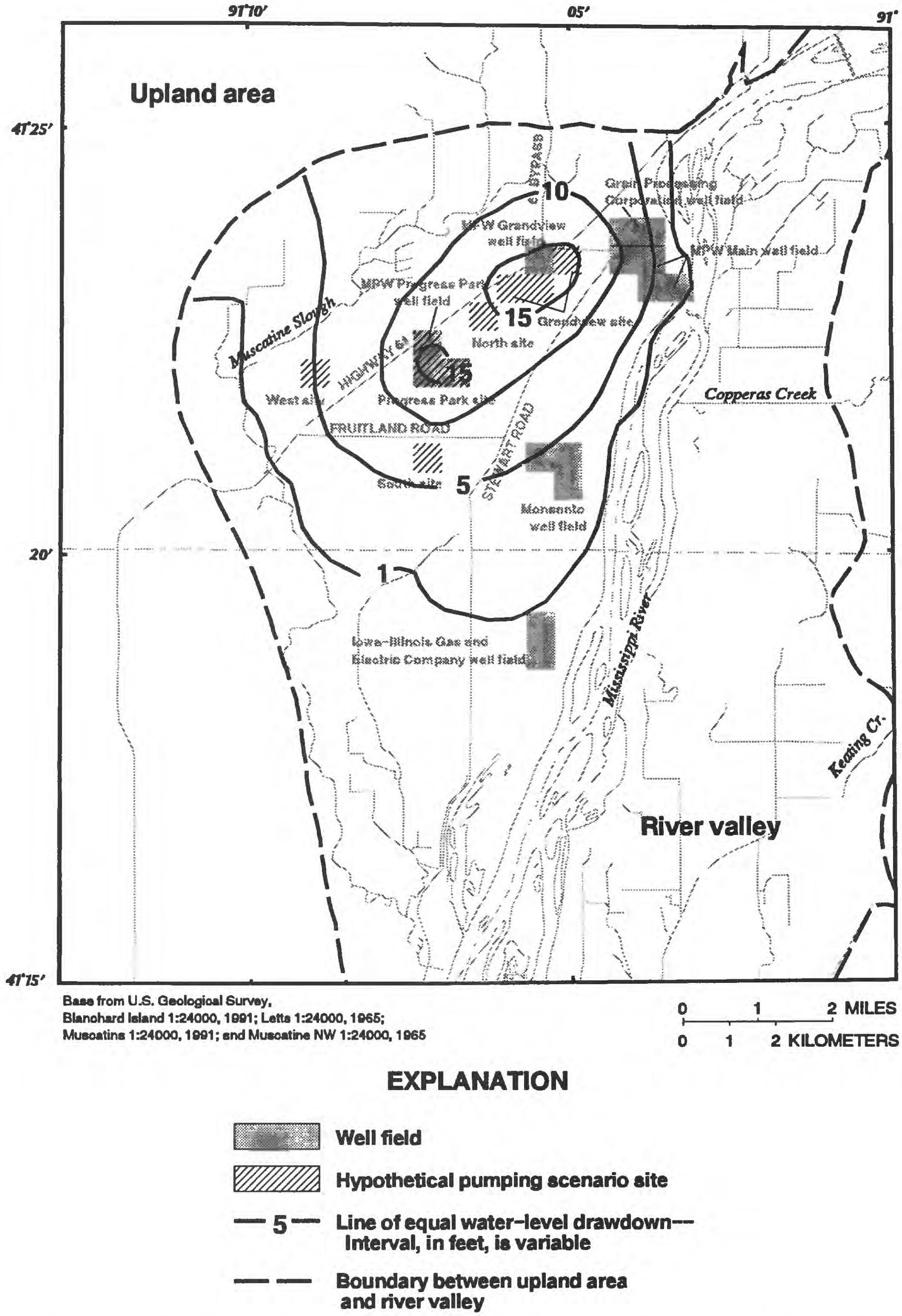
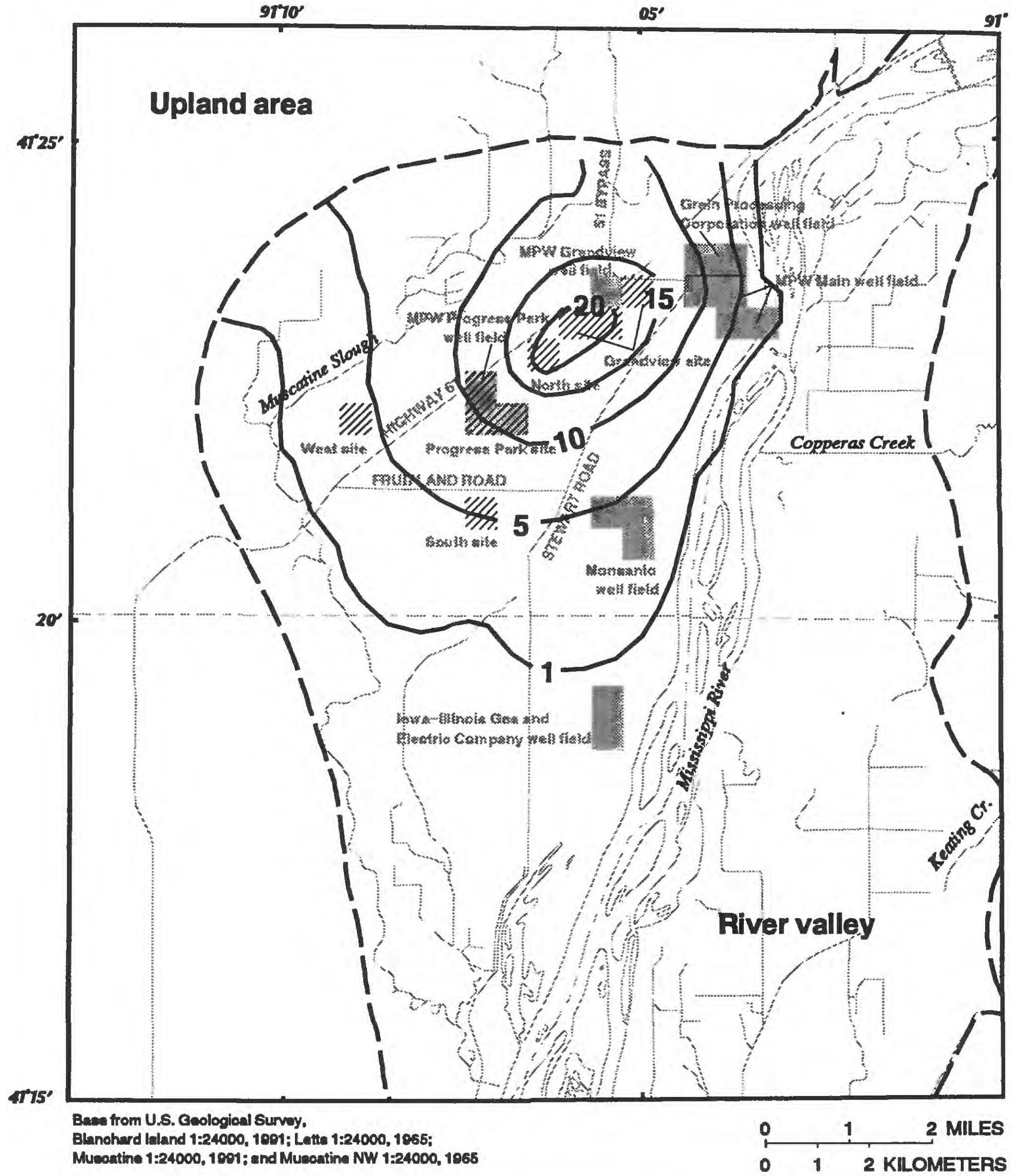


Figure 4. Simulated drawdown caused by hypothetical pumping at the Progress Park and Grandview pumping scenario sites (Progress Park pumping scenario, PP).



EXPLANATION

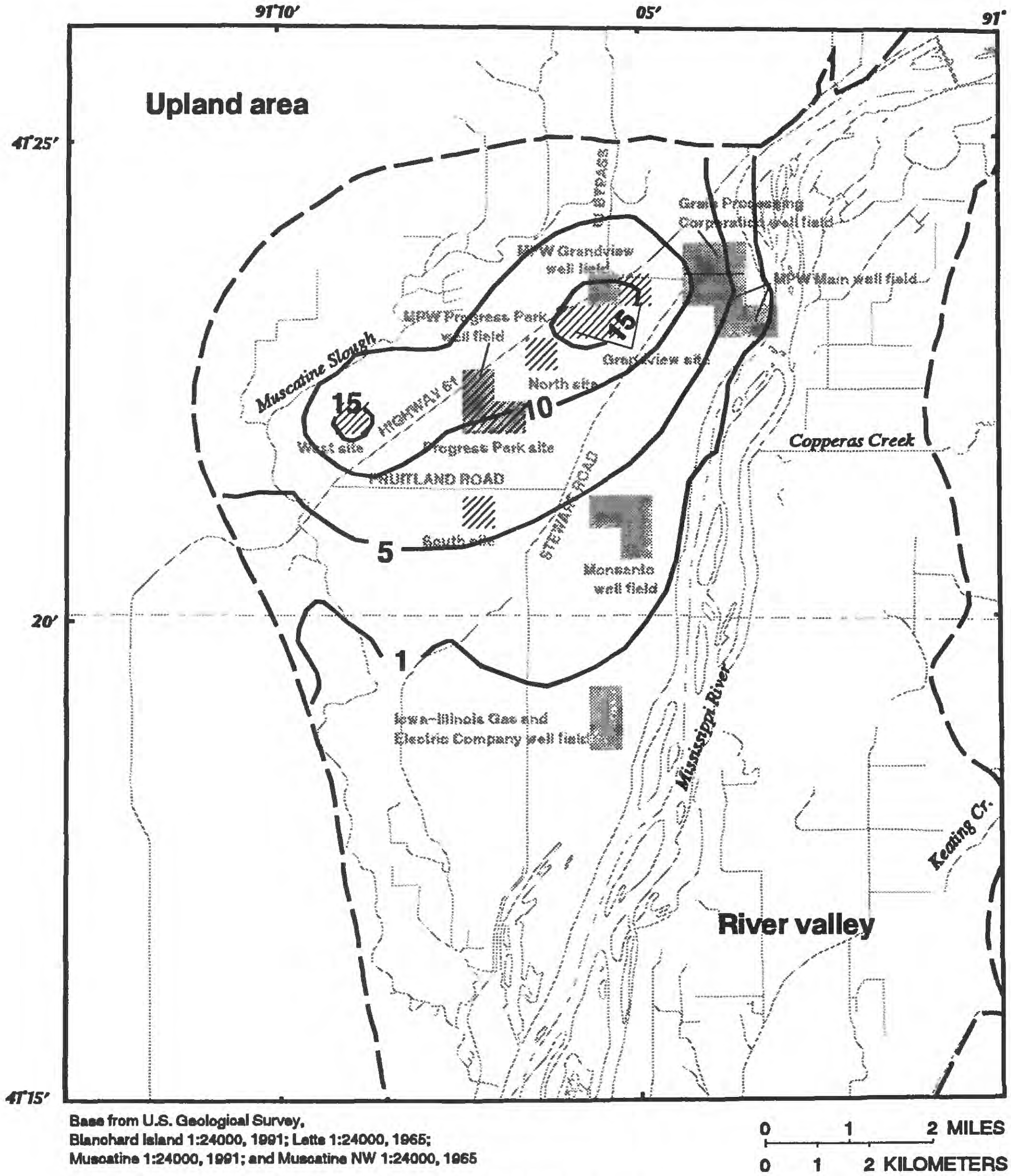
Well field

Hypothetical pumping scenario site

— 5 — Line of equal water-level drawdown--Interval, in feet, is variable

— — Boundary between upland area and river valley

Figure 5. Simulated drawdown caused by hypothetical pumping at the North and Grandview pumping scenario sites (North pumping scenario, N).



EXPLANATION

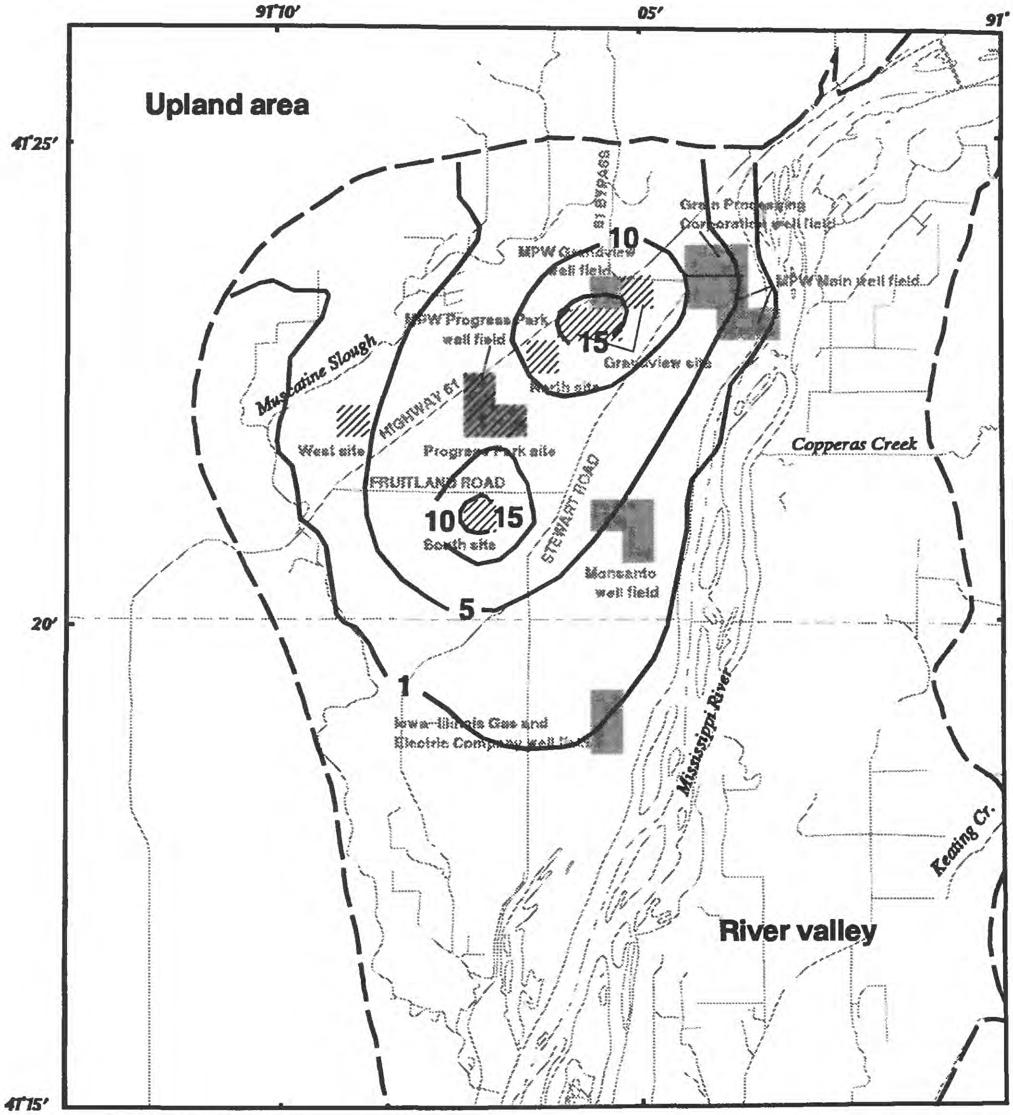
Well field

Hypothetical pumping scenario site

— 5 — Line of equal water-level drawdown--
Interval, in feet, is variable

— — Boundary between upland area
and river valley

Figure 6. Simulated drawdown caused by hypothetical pumping at the West and Grandview pumping scenario sites (West pumping scenario, W).



Base from U.S. Geological Survey,
Blanchard Island 1:24000, 1991; Letts 1:24000, 1965;
Muscatine 1:24000, 1991; and Muscatine NW 1:24000, 1965

0 1 2 MILES
0 1 2 KILOMETERS

EXPLANATION

Well field

Hypothetical pumping scenario site

— 5 — Line of equal water-level drawdown--Interval, in feet, is variable

— — Boundary between upland area and river valley

Figure 7. Simulated drawdown caused by hypothetical pumping at the South and Grandview pumping scenario sites (South pumping scenario, S).

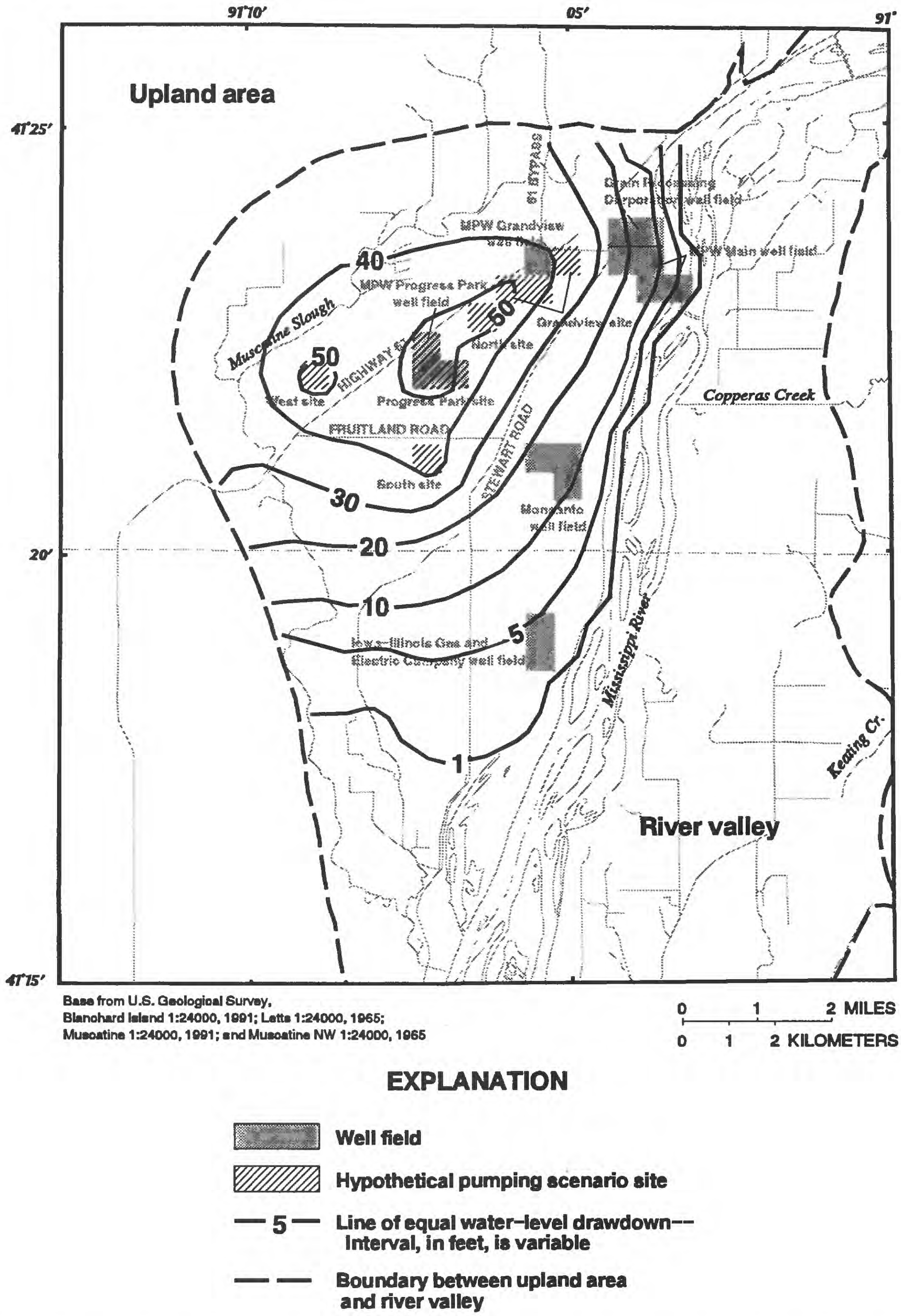


Figure 8. Simulated drawdown caused by cumulative hypothetical pumping at the five pumping scenario sites (Total pumping scenario, TOT).

lated drawdown greater than 10 ft at the site and at MPW Grandview well field. Less than 10 ft of simulated drawdown occurs at the Grain Processing Corporation, MPW Main, and Progress Park well fields (fig. 3).

The Progress Park pumping scenario causes simulated drawdown greater than 15 ft at the MPW Grandview and Progress Park well fields and at the Grandview and Progress Park pumping scenario sites (fig. 4). As much as 10 ft of simulated drawdown occurs at the Grain Processing Corporation and MPW Main well fields.

The North pumping scenario causes simulated drawdown greater than 20 ft at the North and Grandview pumping scenario sites (fig. 5). The larger drawdown compared to the Progress Park pumping scenario is caused by the proximity of the North and Grandview pumping scenario sites (fig. 5). Between 15 and 20 ft of simulated drawdown occurs at the MPW Grandview well field, between 10 and 15 ft of simulated drawdown occurs at the MPW Progress Park well field, and as much as 10 ft of simulated drawdown occurs at the Grain Processing Corporation and MPW Main well fields.

The West pumping scenario causes simulated drawdown greater than 15 ft at the West and Grandview pumping scenario sites and at the MPW Grandview well field (fig. 6). About 10 ft of simulated drawdown occurs at the MPW Progress Park well field, and as much as 10 ft of simulated drawdown occurs at the Grain Processing Corporation and MPW Main well fields.

The South pumping scenario causes simulated drawdown greater than 15 ft at the South and Grandview pumping scenario sites and at the MPW Grandview well field (fig. 7). Less than 10 ft of simulated drawdown occurs at the Grain Processing Corporation, MPW Main, and MPW Progress Park well fields.

Small simulated drawdowns result from the five separate pumping scenarios at the Monsanto and Iowa-Illinois Gas and Electric Company well fields. Simulated drawdown of about 5 ft or less occurs at the Monsanto well field, and simulated drawdown of about 1 ft or less occurs at the Iowa-Illinois Gas and Electric Company well field.

Simulated drawdown caused by cumulative hypothetical pumping at the five pumping scenario sites for the total pumping scenario is greater than 50 ft at the North, Progress Park, and West pumping scenario sites and the MPW Progress Park well field (fig. 8). Simulated drawdown of about 40 ft occurs at the Grandview and South pumping scenario sites and the MPW Grandview well field. Simulated drawdown at the MPW Main well field varies from about 20 ft in the western part to about 5 ft near the Mississippi River. Simulated drawdown between about 10 and 20 ft occurs at the Monsanto well field, whereas simulated drawdown is less than about 5 ft at the Iowa-Illinois Electric Company well field.

The evaluation of drawdown for the six pumping scenarios indicates that hypothetical pumping causes simulated drawdown that varies from about 10 ft to greater than 50 ft relative to February 1993 conditions at the five pumping scenario sites. The simulated drawdown is less than half of the estimated saturated thickness (120 ft to 130 ft) of the alluvium during February 1993 at these sites. Simulated drawdown of about 20 ft occurs in the western part of the Grain Processing Corporation and the MPW Main well fields, where the alluvium had a saturated thickness of about 50 ft in February 1993 (Lucey and others, 1995).

EVALUATION OF SOURCES OF WATER

Water budgets from model simulations provide information on simulated inflows to and outflows from the alluvium. A comparison of water budgets from different model simulations can be made to evaluate quantitative differences in sources of water. The simulated water budgets for the pumping scenario model simulations are presented in table 1. The simulated water budget for the flow model constructed by Lucey and others (1995) is shown for comparison, so that an evaluation of the effect on sources of water relative to February 1993 conditions can be made.

The water-budget components most affected by the simulated hypothetical pumping are river leakage (Mississippi River) and slough leakage (Muscatine Slough). The river leakage inflow rate and corresponding percent of total inflow to the ground-water flow system increase from 5,411,000 ft^3/d and 35.8 percent for February 1993 conditions to 9,867,000 ft^3/d and 50.6 percent in the total pumping scenario. The slough leakage outflow rate and corresponding percent of total outflow decrease from 3,360,000 ft^3/d and 22.3 percent for February 1993 conditions to 1,182,000 ft^3/d and 6.1 percent in the total pumping scenario.

Sources of water to the alluvium include recharge (from precipitation and upland runoff), river leakage, slough leakage, and upward leakage from the bedrock or downvalley flow through the alluvium (Lucey and others, 1995). The primary sources of water (inflows) to the alluvium needed to balance the increased ground-water withdrawals (outflows) caused by the hypothetical pumping are a combination of increased river leakage and decreased leakage to the slough. Compared to February 1993 conditions, larger inflow rates occur as river leakage from the Mississippi River (table 1) for the six pumping scenarios. However, smaller outflow rates for slough leakage compared to February 1993 conditions indicate that an important source of water for hypothetical pumping is ground-water discharge that would have become streamflow in the slough.

The increase in leakage from the Mississippi River to the ground-water flow system and the decrease in leakage to the Muscatine Slough from the ground-water flow system (decreased ground-water discharge) for the six pumping scenarios compared to February 1993 conditions are shown graphically in figure 9. The stress on the ground-water flow system caused by removal of water by hypothetical pumping for each of the five pumping scenarios is compensated for, about equally, by an increase in river leakage and a decrease in ground-water discharge to Muscatine Slough. For example, hypothetical pumping of about 2,000,000 ft^3/d for the Grandview pumping scenario results in about 1,000,000 ft^3/d more leakage from the Mississippi River and about 1,000,000 ft^3/d less ground-water discharge to the slough compared to the February 1993 conditions. A similar relation exists between hypothetical pumping, leakage from the Mississippi River, and ground-water discharge to the slough for each of the five individual pumping scenarios.

For the total pumping scenario, changes in the ground-water flow system are dominated by leakage from the Mississippi River, as the rate of leakage from the river to the alluvium is about twice the rate of ground-water discharge to the slough. Cumulative hypothetical pumping at the five pumping scenario sites of about 6,600,000 ft^3/d results in about 4,400,000 ft^3/d more leakage from the Mississippi River and about 2,200,000 ft^3/d less ground-water discharge to the slough compared to February 1993 conditions. The greater stress on the ground-water flow system caused by the total pumping scenario compared to the five individual pumping scenarios results in the river leakage becoming more dominant as a source of water compared to decreased ground-water discharge to the slough.

The percentage increase in leakage from the Mississippi River to the ground-water flow system and the percentage decrease in leakage to the Muscatine Slough from the ground-water flow system (decreased ground-water discharge) for the six pumping scenarios compared to February 1993 conditions are shown in figure 10. The Mississippi River is a source for about 20 percent more water for the Grandview pumping scenario, about 30 percent more water for the Progress Park, North, South, and West pumping scenarios, and about 80 percent more water for the total pumping scenario. Leakage to the slough is decreased about 30 percent for the Grandview pumping scenario, about 40 to 50 percent for the Progress Park, North, South, and West pumping scenarios, and about 60 percent for the total pumping scenario.

Increased pumping at the pumping scenario sites could affect long-term water quality and hydrology in the study area. The greater amounts of river leakage might affect overall ground-water quality in the alluvium. The lesser amounts of ground water being discharged to streamflow could have a long-term impact on the hydrology of the slough and adjacent wetland areas.

LIMITATIONS IN USE OF MODEL RESULTS

The flow model constructed by Lucey and others (1995) and modified for use in this study estimates general effects of additional ground-water withdrawals from the alluvium. However, the following model limitations should be considered:

1. The model, which discretizes the study area into 2,000-ft by 2,000-ft cells, provides information to evaluate the ground-water flow system on a large scale. The model cannot accurately simulate water-level drawdown near individual pumping wells or be used to accurately simulate source areas for individual wells; a model with a finer grid would be required for such detailed analysis.

2. Model input parameters, such as aquifer characteristics and recharge rate, are applied at the center (node) as an average value for the model cell. The assumptions of uniformity for the entire cell can introduce inaccuracies because of the heterogeneous nature of geologic materials and variability of climatic conditions.

Table 1. Water budgets indicated by model simulations

[FEB93, February 1993 simulation assumed to represent equilibrium condition (Lucey and others, 1995); GV, Grandview pumping scenario; PP, Progress Park pumping scenario; N, North pumping scenario; W, West pumping scenario; S, South pumping scenario; TOT, total pumping scenario; Inflow, water being added to the ground-water system; rate, units are thousands of cubic feet per day; %, percent of total inflow or outflow; Outflow, water being removed from the ground-water system; slough leakage, from or to Muscatine Slough and its associated drain network in Iowa; <, less than; drain leakage, to the drain network in Illinois]

Water-budget component			FEB93	GV	PP	N	W	S	TOT
Recharge - Precipitation and upland runoff	Inflow -	rate	9,025	9,025	9,025	9,025	9,025	9,025	9,025
		%	59.8	55.9	54.0	53.7	54.5	54.0	46.2
	Outflow -	rate	0	0	0	0	0	0	0
		%	0	0	0	0	0	0	0
River leakage - Mississippi River	Inflow -	rate	5,411	6,480	7,049	7,162	6,909	7,021	9,867
		%	35.8	40.1	42.1	42.6	41.7	42.0	50.6
	Outflow -	rate	121	123	113	114	117	111	98
		%	.8	.8	.7	.7	.7	.7	.5
River leakage - Copperas and Keating Creeks	Inflow -	rate	236	236	236	236	236	236	236
		%	1.6	1.5	1.4	1.4	1.4	1.4	1.2
	Outflow -	rate	291	292	292	292	292	292	292
		%	1.9	1.8	1.7	1.7	1.8	1.7	1.5
Slough leakage	Inflow -	rate	425	405	410	394	394	431	394
		%	2.8	2.5	2.5	2.3	2.4	2.6	2.0
	Outflow -	rate	3,360	2,374	1,891	1,987	1,655	1,834	1,182
		%	22.3	14.7	11.3	11.8	10.0	11.0	6.1
Upward leakage from bedrock or flow though alluvium	Inflow -	rate	[1]0	[1]0	[1]0	[1]0	[1]0	[1]0	[2]0
		%	<.1	<.1	<.1	<.1	<.1	<.1	<.1
	Outflow -	rate	155	154	153	153	153	153	152
		%	1.0	1.0	.9	.9	.9	.9	.8
Pumping	Inflow -	rate	0	0	0	0	0	0	0
		%	0	0	0	0	0	0	0
	Outflow -	rate	6,091	8,112	9,267	9,267	9,267	9,267	12,732
		%	40.3	50.2	55.1	54.8	55.9	55.3	65.1
Drain leakage	Inflow -	rate	0	0	0	0	0	0	0
		%	0	0	0	0	0	0	0
	Outflow -	rate	5,095	5,093	5,093	5,093	5,093	5,093	5,090
		%	33.7	31.5	30.3	30.1	30.7	30.4	26.0
Total budget	Inflow -	rate	15,097	16,146	16,720	16,817	16,564	16,713	19,522
		%	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Outflow -	rate	15,113	16,148	16,809	16,906	16,577	16,750	19,546
		%	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] < 10 cubic feet per day
[2] < 30 cubic feet per day

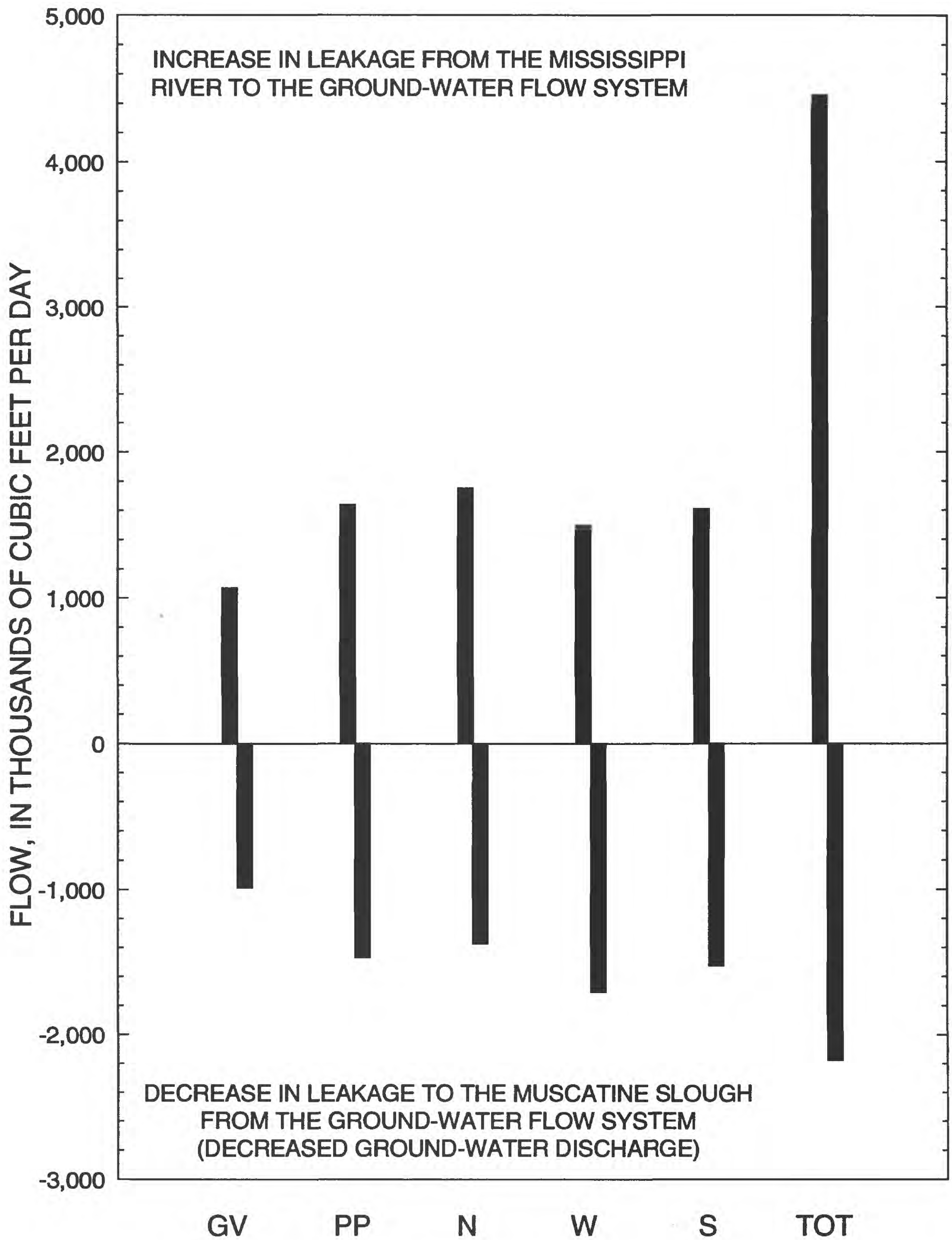


Figure 9. Change in leakage for the pumping scenarios compared to February 1993 conditions (GV, Grandview scenario; PP, Progress Park scenario; N, North scenario; S, South scenario; W, West scenario; TOT, Total pumping scenario).

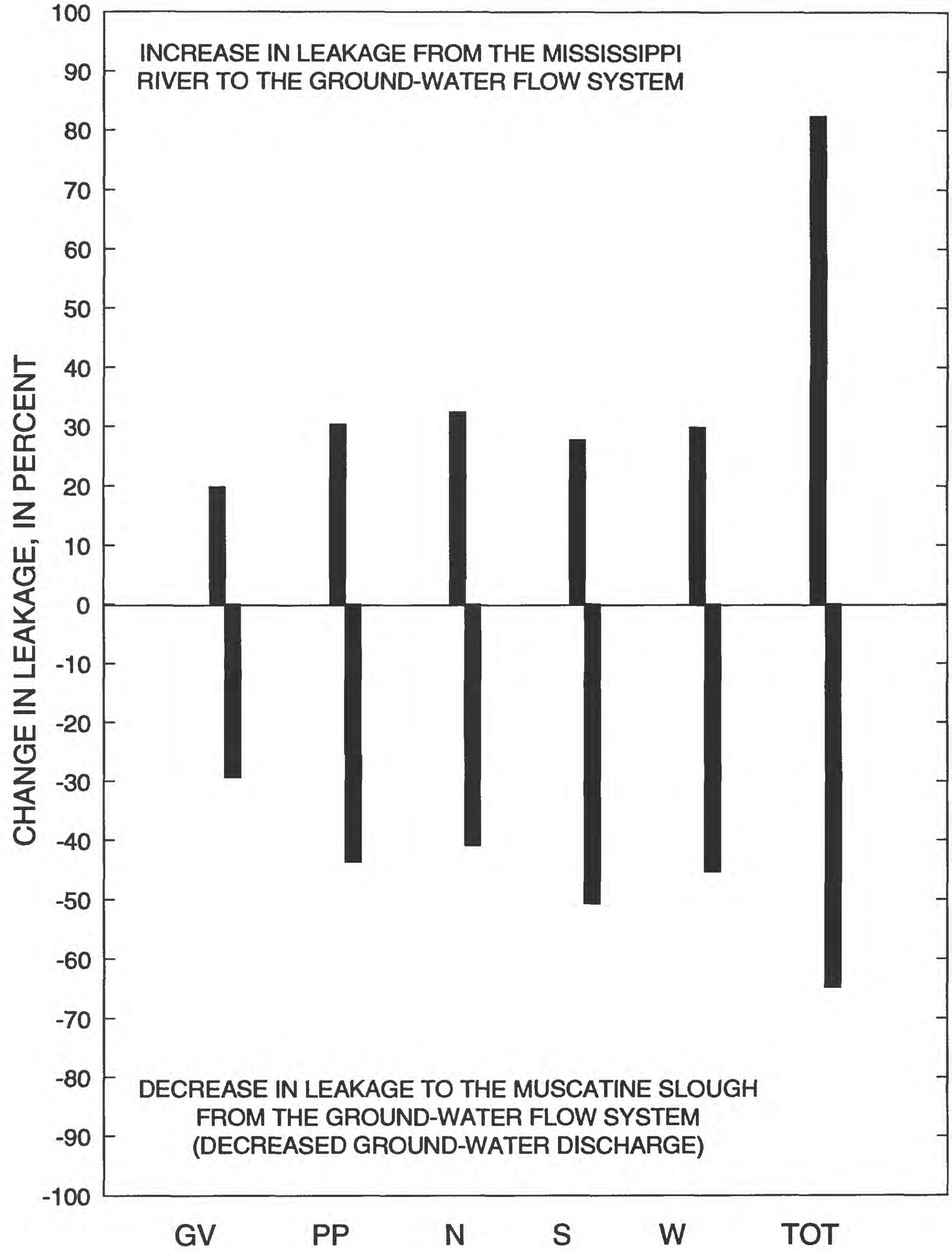


Figure 10. Percentage change in leakage for the pumping scenarios compared to February 1993 conditions (GV, Grandview scenario; PP, Progress Park scenario; N, North scenario; S, South scenario; W, West scenario; TOT, total pumping scenario).

3. The steady-state model assumes that inflows to the ground-water system equal outflows. If this was not the case in February 1993, the change in ground-water storage would be a source of model error. For example, water levels could have been either rising or falling during the assumed equilibrium condition.

4. The simplified steady-state flow model does not account for dynamic (transient) conditions (natural or development-related). The steady-state model does not indicate time needed to reach new equilibrium conditions. Attaining equilibrium might take many years and is complicated by varying climatic and hydrologic conditions; noncontinuous pumping and pumping that is cycled among well fields; and changing and seasonally varying irrigation pumpage (not included in this model). Large drawdowns for the six pumping scenarios indicate that aquifer storage would be an important component of the water budget until the system approximates equilibrium. Simulated drawdown might not represent actual drawdown during continued development of the ground-water resource, as pumping from newly-constructed wells periodically increases stress on the ground-water flow system before equilibrium has been attained for the stress caused by current pumping. Further model analysis to account for changes in aquifer storage and changing conditions would enable improved understanding of such complicating factors.

SUMMARY

Muscatine Power and Water and the U.S. Geological Survey conducted a cooperative study to evaluate drawdown and quantitative changes in sources of water in the Mississippi River alluvium caused by hypothetical pumping. A steady-state, ground-water flow model was constructed by Lucey and others (1995) to simulate February 1993 hydrologic conditions, which were assumed to be an acceptable estimate of the ground-water system at equilibrium. The flow model was modified for this study to simulate six hypothetical pumping scenarios: five pumping scenarios to simulate hypothetical pumping at five pumping scenario sites, and one total pumping scenario to simulate cumulative hypothetical pumping from the five pumping scenario sites. The number of wells and the amounts of hypothetical pumping at each of the five pumping scenario sites were selected in consultation with Muscatine Power and Water.

The evaluation of drawdown for the six pumping scenarios indicates that hypothetical pumping causes simulated drawdown that varies from about 10 ft to greater than 50 ft relative to February 1993 conditions at the five pumping scenario sites. The simulated drawdown is less than half of the estimated saturated thickness (120 ft to 130 ft) of the alluvium during February 1993 at these sites. Simulated drawdown of about 20 ft occurs in the western part of the Grain Processing Corporation and MPW Main well fields where the alluvium had a saturated thickness of about 50 ft in February 1993.

The primary sources of water (inflows) to the alluvium needed to balance the increased ground-water withdrawals (outflows) caused by the hypothetical pumping are a combination of increased river leakage and decreased leakage to Muscatine Slough. Compared to February 1993 conditions, larger inflow rates occur as river leakage from the Mississippi River for the six hypothetical pumping scenarios. However, the smaller outflow rates for slough leakage compared to February 1993 conditions indicate that an important source of water for hypothetical pumping is decreased ground-water discharge that would have become streamflow in the slough.

The water-budget components most affected by hypothetical pumping are river leakage (Mississippi River) and slough leakage (Muscatine Slough). Compared to February 1993 conditions, the Mississippi River is a source for about 20 percent more water for the Grandview hypothetical pumping scenario, about 30 percent more water for the Progress Park, North, South, and West hypothetical pumping scenarios, and about 80 percent more water for the total hypothetical pumping scenario. Leakage to the slough is decreased about 30 percent for the Grandview hypothetical pumping scenario, about 40 to 50 percent for the Progress Park, North, South, and West hypothetical pumping scenarios, and about 60 percent for the total hypothetical pumping scenario.

Increased pumping at the pumping scenario sites could affect long-term water quality and hydrology in the study area. The greater amounts of river leakage might affect overall ground-water quality in the alluvium. The lesser amounts of ground water being discharged to streamflow could have a long-term impact on the hydrology of the slough and adjacent wetland areas.

The simplified steady-state flow model does not account for dynamic (transient) conditions (natural or development-related). The steady-state model does not indicate time needed to reach new equilibrium conditions. Attaining equilibrium might take many years and is complicated by varying climatic and hydrologic conditions; noncontinuous pumping and pumping that is cycled among well fields; and changing and seasonally varying irrigation pumpage (not included in this model). Further model analysis to account for changes in aquifer storage and changing conditions would enable improved understanding of such complicating factors.

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